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THE AMERICAN RUBBER CRISIS

THE occupation of Malaya and the Dutch East Indies by the Japanese cut off the United Nations from sources which formerly produced 90 per cent. of the world's rubber. This decisive enemy action has had a particularly serious effect on America's supplies of rubber since this country used more than half of all the rubber consumed throughout the world and is now urgently in need of large quantities of new rubber not only to manufacture the wide range of war products required by the armed forces of the United Nations but also to keep its essential transport services functioning. According to an article recently published in *Science** it is considered that the solution of the present rubber crisis in the United States depends on whether the gap can be bridged until synthetic rubber manufacturing facilities now under construction produce the large quantities of rubber required for military and other essential needs.

Statistically the position is as follows. The rubber plantations of the world which cover a planted area of approximately 9,000,000 acres had a production capacity in 1941 of 1,600,000 tons a year. The world's consumption from 1939 to 1941—a record three-year period—was at the rate of about 1,100,000 tons a year, which left a potential surplus of 50 per cent. In June, 1940, the stocks of rubber in the United States totalled only 168,000 tons, the consumption for that same year being 648,000 tons. The position of about three and a half months' stock was anything but a healthy one for the country and for its economy. Fortunately, thanks to the farsightedness of the American Government, the United States had secured, by the time the Eastern plantations were captured in 1942, approximately 600,000 tons of rubber which represents a normal year's supply for the country. These stocks of crude rubber to which must be added stocks of scrap rubber and reclaimed rubber will have to bridge the gap until synthetic rubber becomes adequate. It is also estimated that the rubber in tyres on cars now on America's highways amounts to 1,200,000 tons. It will be evident from these figures that the real crisis in rubber in the United States will come during the course of this year. How it will be overcome will depend mainly upon the ability to conserve rubber and to produce synthetic rubber.

*Crisis in Rubber, J. L. Collyer. *Science*, Vol. 97, No. 2506, pp. 32-36.

Although early in June, 1940 the B. F. Goodrich Company introduced for sale to car owners a tyre in which American general purpose synthetic rubber replaced natural rubber by more than 50 per cent. it was not until January, 1942 that a large-scale synthetic rubber programme was announced by the American Government. This originally provided for the production of 400,000 tons a year of butadiene synthetic rubber at an estimated cost of $400,000,000. Provisions have since been made to construct plants designed to produce 705,000 tons of synthetic rubber of the butadiene-styrene type, 132,000 tons of butyl rubber and 40,000 tons of neoprene, or a total of approximately 900,000 tons a year at an estimated cost of $700,000,000. In addition, Canada is carrying out a programme for creating a capacity of 40,000 tons a year of the butadiene-synthetic type while it is believed that Russia has been producing as much as 50,000 tons a year.

The butadiene type rubber is referred to as AA, an abbreviation for All-American. "The basic raw materials are three parts of butadiene and one part of styrene. Butadiene is a gas which can be made either by cracking petroleum, or by removing hydrogen from butylene, a by-product in the manufacture of high octane gasoline, or by catalytic conversion from alcohol. No matter from what basic raw material it is prepared, the resulting butadiene when properly purified is the same. The other raw material styrene can be most conveniently manufactured from the aromatic hydro-carbon benzene obtained from coal tar and ethylene, a gas which occurs as a by-product in most petroleum refineries. The responsibility for the construction and operation of the plants to produce the butadiene and styrene to be used in the manufacture of All-American synthetic rubber has been delegated to the petroleum and chemical industries.

To rubber companies has been given the task of building the polymerization or synthetic rubber plants and of producing AA rubber from raw materials supplied to them mainly by the chemical and petroleum industries.

In the polymerization process, butadiene which has been liquefied by compression and cooling is mixed with styrene, soapy water and several minor "salt and pepper" ingredients. This mixture is then heated and stirred under pressure, whereupon the molecules of butadiene and styrene polymerize or join together to form an emulsion of synthetic rubber which is quite similar in appearance to the latex obtained from rubber-producing trees. From here on the process of obtaining sheet rubber is like that used for natural rubber."

Tyres which contain 99.84 per cent. of this synthetic rubber are now being tested. It has been found that passenger car tyres and small-size truck and bus tyres give excellent service. In the manufacture of larger-size truck and bus tyres, however, urgently needed for military use, several difficult problems have arisen owing to the fact that synthetic rubber tyres in service have been found to generate more heat than natural rubber tyres, thus causing an earlier failure. Work is being done on this problem and it is confidently hoped that it will be solved. Almost all essential rubber articles can be made from AA rubber including hundreds of important products used by the armed forces.

It is unlikely that the production of synthetic rubber will fully meet all necessary requirements until 1944 at the earliest. In 1942 about 32,000 tons of synthetic rubber were produced, practically all from privately financed plants. This year the American Government plants are expected to enter large scale production and estimates for all types of artificial rubber range from 300,000 to 500,000 tons, and in 1944, from 700,000 tons to 1,000,000 tons.

It is predicted that the end of this year will see the stocks of rubber in America and in the hands of the Allies near exhaustion. Apart from small quantities of natural rubber which will be available from South America, Africa, and as a result of the cultivation of guayule, the main source of supply must in future be synthetic rubber. Everything, accordingly, is being done in America to speed up to the utmost the production of this rubber in as large quantities as possible in order that the country may meet its own vital requirements and those of its military forces.

THE INTER-AMERICAN INSTITUTE OF AGRICULTURAL SCIENCES, TURRIALBA

A new Inter-American Institute of Agricultural Sciences has been established at Turrialba where the Costa Rican Government has provided 1,200 acres of the finest upland soil to be found in the American tropics. Formal title was transferred to the institute only recently, although initial phases of actual field work had already been in progress for some time. This locality, at 2,000 feet above sea level, was chosen because less than two hours' ride by car or train can carry the investigator through an almost complete cross section of tropical American conditions. The soils of the region are volcanic, temperatures average in the middle 70's, rainfall amounts to 110 inches a year, and the humidity is high.

Scientific work at the institute is to be entirely research on the post-graduate level; no undergraduate courses are contemplated. Until the war is over, only temporary buildings will be erected but plans for the permanent ones are already drawn up, and construction can go forward rapidly once materials and manpower are released.

Research is already in progress on rubber, cinchona, foodstuffs and tropical hardwoods. Work will begin soon on plants providing oil fibres and insecticides. Dr. Earl N. Bressman is director of the Institute.—(*From Science*, Vol. 97, No. 2517.)

TERMITES AND THE FERTILITY OF SOILS

BY

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Introduction

It has long been known that the activities of termites may have important effects on soil fertility. In 1886 Drummond wrote "On the termite as the tropical analogue of the earthworm", recognising that termite burrows and mounds might have effects comparable to those described in Darwin's classic work on the common earthworms of Europe. It is even more obvious that termites which eat dead wood promote its disintegration and that they may thus play an important part in the cycles of organic and inorganic material in the soil. Most of the termites are earth-dwellers, to a much greater extent than is generally recognised. They occur in such enormous numbers in many lands that any changes brought about by them are likely to be of considerable importance. Interest in the relation of the termites to soil fertility has increased in recent years but few comprehensive statements on the subject appear to have been published. This paper is an attempt to outline the many aspects of the problem and to suggest lines of investigation. It is based partly on the writer's observations in Trinidad, British West Indies, where there is a rich termite fauna of continental origin.

Most of the literature* on this subject is limited to casual observations. No precise quantitative data have been published on such questions as the numbers of termites in soils, the extent of their subterranean passages, and the amount of soil carried by them above the surface of the ground. Moreover, the feeding habits of most of the soil-dwelling termites have not been adequately studied, and scarcely anything is known about their digestive processes. Detailed investigations on the composition of the building materials of termites are limited to a few chemical analyses of samples from termite mounds. An adequate understanding of the influence of termites on soil fertility is obviously impossible at present.

The following discussion may be introduced by a brief general description of the status of termites in a typical forest in Trinidad. It will apply to most wooded parts of the island, but in particular to areas of moderate to heavy rainfall (70 to 110 inches annually), with trees 100 to 150 feet high, extensively overgrown by vines and epiphytes, and with a thick litter of fallen leaves and humus.

Almost all dead wood in such a forest is sooner or later extensively invaded by termites belonging to over fifty species. The attack is initiated by a few species, especially of *Heterotermes*, *Microcerotermes* and *Nasutitermes* and members of the family Kalotermitidae, and as fungal decay proceeds these are followed by innumerable species which feed on the rotting wood. Dead tree trunks and fallen branches are most extensively attacked, but dead limbs on growing trees are reached by covered runways built especially by *Microcerotermes* and *Nasutitermes*. The decay and complete disintegration of dead wood is everywhere greatly accelerated by enormous numbers of termites.

Even casual inspection shows that great quantities of soil are carried above the surface by the termites. Exposed nests, built largely or partially of earth, occur in considerable numbers. The commonest are the arboreal nests of *Nasutitermes* and *Microcerotermes*. Less frequent, but together sufficient to result in considerable movement of soil, are the nests of *Termes* (*Mirotermes*), *Armitermes*, *Cornitermes* and others built on the ground, in the form of low mounds or against the base of trees. Many hollow decaying trunks and branches contain large amounts of earthy material, brought there as a partial filling of their galleries, or as nesting material, by *Heterotermes*, *Termes* (*Mirotermes*), *Coptotermes* and other termites. Covered runways built largely of soil extend far up the trunks and branches of most of the trees. They are made chiefly by *Nasutitermes* and *Microcerotermes*, between their arboreal nests and the ground or leading to dead portions of growing trees.

Finally, in the soil of the forest floor are the innumerable subterranean passages made by all species of termites, excepting only the Kalotermitidae. In many Trinidad forests burrowing termites may be found below every square foot of the surface.

The above description applies to the parts of Trinidad which are most favourable to the development of a very rich termite fauna. In cultivated forest such as cacao, rubber or teak plantations, and in natural forest in relatively dry areas (50 to 70 inches), where a less varied fauna and fewer individual termites occur, the consumption of dead wood probably proceeds less rapidly, and the movement of soil above the surface and burrows in the ground are of greatly reduced extent. In cultivated fields such as those of sugar cane, the termite fauna is so reduced that it probably has little effect on the nature of the soil.

The writer has not visited the tropics of Africa and Asia, but it seems certain that most of the above account of the prodigious activity of termites in a neotropical forest is applicable in much

* Some recent publications by Troll, Idenburg, Steenis and others were not available to the author at the time of writing. Kalshoven's important paper (*see* References) has been seen only in abstract.

greater degree to similar forests throughout the Old World tropics. In Africa, where the termites attain their most exuberant development, activities on a similar scale may occur even in relatively dry areas. The great number and size of termite mounds in many dry and sparsely wooded parts of Africa indicates populations of enormous proportions.

The Habitats of Termites in Relation to the Soil

As regards their mode of life in relation to the soil, the termites fall into two natural groups :

(1) The termites of the family Kalotermitidae, the so-called dry-wood termites, which live almost exclusively within dead wood. Very few species enter the soil, and these to an insignificant extent. The only activities of the Kalotermitidae which affect soil fertility are the consumption and disintegration of dead wood. These may be of some importance, especially as most species attack wood as soon as it dies and they are thus among the first agents of decay ; but the colonies of the Kalotermitidae are relatively small and their activities are of minor importance in comparison with those of other termites, especially in the tropics. In the subtropics wood-boring beetles may be more important than termites.

(2) The termites of all other families : Mastotermitidae, Hodotermitidae (excluding the small subfamily Termopsinae, which Emerson, 1942, has recently transferred from the Kalotermitidae to the Hodotermitidae), Rhinotermitidae and Termitidae. These are all soil-dwellers. Though many of them feed and build nests above ground, they spend almost all of their lives in intimate contact with the soil, in subterranean passages or in nests and runways built partly of earth, and even the galleries which they excavate in wood may be lined with materials derived from the soil. Many of them swallow soil in large quantities.

The termites of group (2) may be subdivided into the following groups, which bear no relation to the classification of these insects into families and genera, since even closely related species may differ widely in habitat :

(*2a*) Exclusively subterranean termites, living in nests and passages underground and coming above the surface only during the brief nuptial flight of the young reproductives. In Trinidad there are many species in this group, especially in the genus *Anoplotermes*, and some of them occur in great numbers in certain soils, particularly in forests. They presumably have a considerable influence on soil fertility, owing to the extent of their subterranean passages and the amount of soil ingested by them. Unfortunately the biology of termites of such cryptic habit has received little attention and their numbers and importance in other countries have not been recorded.

(*2b*) Builders of exposed nests (termitaria), which may be of the mound type, resting on the ground, or arboreal, on the trunks and branches of trees and shrubs. Mound nests range from heaps of earth a few inches high to the enormous edifices, over 20 feet high and weighing many tons, which are striking features of the landscape in parts of Africa, and on a slightly smaller scale in Asia, Australia and South America. Arboreal nests are limited to a few feet in diameter. The division between mound and arboreal nests is not always sharply defined, many nests being built on the lower portions of tree trunks or stumps, with their bases in contact with the ground. All builders of exposed nests enter the ground to seek food, water and building materials, and many of them construct extensive systems of covered passages leading to dead wood and other plant remains, which in some cases are plastered with earth. Wherever these termites are abundant, they carry large quantities of soil above the surface.

(*2c*) Termites with subterranean nests, but seeking food above the surface, often by way of covered passages. In this group are most of the termites responsible for damage to buildings, especially in the genera *Coptotermes*, *Heterotermes* and *Reticulitermes*. Though some of them do little building above ground, they carry considerable quantities of soil above the surface, to form a lining or partial filling of their galleries in wood on which they feed. In Trinidad most of the galleries of the common *Heterotermes tenuis* (Hag.) are lined with cement-like material derived from the soil and the wide galleries of *Coptotermes testaceus* (L.) are more or less completely filled with similar material. This habit has received little attention and its significance is unknown. It results in a considerable movement of soil above the surface.

Few detailed observations have been made on the depths to which termite subterranean passages descend. In Trinidad forests they are most abundant in the top soil, within six inches of the surface, where there is a high content of organic matter. In parts of the island where the dry season causes desiccation of the upper layers of soil, the termites presumably seek water at considerable depths, but it is unlikely that extensive tunnelling occurs far below the surface. Kalshoven (1941) states that termites in the East Indies seek the level of ground-water at depths of at least 4 metres. In arid countries penetration to much greater depths occurs. Most subterranean nests are probably built within a few feet of the surface, but a chamber of an African harvester termite (*Hodotermes mossambicus* Hag.) at a depth of 20 feet is recorded by Coaton (1937).

The Feeding Habits of Termites

The feeding habits of the majority of termite species have not been adequately studied, but the general nature of the diet of the termites as a whole is well known. It consists mainly of cellulose and in the case of many if not most species, is derived from plant remains in an advanced state of decay. The following kinds of food may be distinguished :

Living wood. This is attacked by relatively few termites, such as species of *Coptotermes* which damage rubber trees in Malaya and timber trees in Australia, and of *Neotermes* attacking tea in Ceylon and teak in Java. No termites are known to be dependent on a diet of live wood and probably in most, if not all cases, the attack begins on dead tissues from which live wood is invaded secondarily.

Living grass and other herbs. The harvester termites, mostly of the genus *Hodotermes* in Africa and Central Asia, cut leaves of living grass, which they store in their subterranean galleries. The effect of these termites in denudation and erosion of African velds is discussed below.

Sound, dead wood. This is the chief diet of the Kalotermitidae, Rhinotermitidae and many of the Termitidae, and these termites, together with fungi, are the principal agents in the disintegration of dead wood in the tropics. All of them may continue to feed on the rotting wood, but many of them, especially in the Kalotermitidae, have a preference for wood in fairly sound condition. As Kalshoven (1941) has remarked, the rate at which these termites consume dead wood in forests is often exaggerated, as the heart-wood of many species is resistant to them. In the writer's experience in Trinidad forests the fungi play a greater part than the termites in the destruction of dead timber.

Rotting wood. Wood in various stages of decay is subject to attack by most termites and many species, especially in the family Termitidae, appear to feed on wood only after fungal decay is well advanced.

Dead leaves, herbaceous stems, etc. The extent to which these are consumed by termites is not readily estimated. In parts of Africa and Asia herbaceous vegetable remains may be rapidly removed by foraging termites, often working in covered passages (*see*, for example, Kalshoven, 1941, Harris, 1936 and Anon., *Nigerian Forester*, 1940). In Trinidad activities of this kind have not been observed by the writer—many termites feed inside such materials as fibrous stems and petioles, but in general dead leaves do not seem to be eaten until they have reached or approached the condition of humus. There is little information from most countries to indicate the extent to which dead vegetation other than woody tissues is eaten by termites.

Humus. It is apparent from the above paragraphs that the food of a majority of the termites is decaying vegetable matter, but no precise observations appear to be recorded on the state of decay beyond which it ceases to serve as food for termites. Kalshoven (1941) states that certain species (*Capritermes* spp.) appear to feed wholly upon humus. Corbett and Miller (1936) write that the food of *Termes javanicus* Holmg., a subterranean species, is presumably "rotting organic matter in the soil". Hegh (1922) quotes Fuller's (1918) belief that *Cubitermes bilobatus* Hav. feeds like an earthworm on soil full of humus and Silvestri's opinion is that species of *Anoplotermes* in West Africa and *Cornitermes striatus* Hag. in South America feed on "terre végétale", Hegh remarking that this mode of feeding is probably not rare among termites. Observations in Trinidad suggest that Hegh's assumption is not only justified, but is an understatement of the case. Examination of the contents of the alimentary canal of Trinidad termites shows that they consist of soil, apparently swallowed indiscriminately without selection of organic particles, in the following species of Termitidae: *Anoplotermes* (all or most of the numerous species in Trinidad), *Cornitermes labralis* Holmgren, *Cavitermes tuberosus* Emerson, *Crepititermes verruculosus* Emerson. In *Armitermes holmgreni* Snyder, *Termes* (*Mirotermes*) *hispaniolae* (Banks), *Neocapritermes angusticeps* Emerson and some species of *Subulitermes*, soil appears to be an important part of the diet though less conspicuously than in the preceding list. (A paper on the ingestion of soil by termites in Trinidad is in preparation). It thus appears that a majority of the species of the family Termitidae in Trinidad feed largely or partially on organic matter which has been incorporated into the soil, and it is likely that the same is true in many other parts of the tropics. Wherever termites of this habit occur in large numbers, they must bring about great changes in the physical and chemical nature of the soil.

Fungi cultivated in "fungus gardens". The nests of many tropical termites, both mound and subterranean, contain "fungus gardens" similar to those of parasol ants such as *Atta*. The substratum on which the fungi grow appears to consist mainly of vegetable remains such as comminuted wood, altered in greater or less degree by the termites. It is generally accepted that the termites eat portions of the fungi, though Bathellier (1927), Grassé (1937) and Heim (1940) believe that the gardens serve as nurseries for the young termites in which fungi grow incidentally and that they are not cultivated as an important item in the termites' diet.

The digestive processes of termites have been studied extensively only in the case of the primitive *Zootermopsis*, and there is little information to indicate what materials are returned to the soil in termite faeces. Cleveland (1925) and Holdaway (1933) believe that lignin is unaffected by their digestive juices and it may be assumed that lignin in the form of undigested food is an important constituent of their building materials.

Building Materials

Termite constructions, other than mere excavations, include nests (termitaria) both above and below ground level, covered runways built in exposed situations, and materials lining or partially filling their galleries in wood. The principal constituent of all three kinds of structure is soil, mixed with varying amounts of organic matter from other sources. The soil may be carried

from underground in the workers' jaws, but it may be assumed in the case of termites which ingest soil that large amounts are carried in their alimentary canals and used for building in the form of faeces.

The origin of building materials other than soil has not been adequately studied, because of the difficulty of direct observation on activities which normally occur under cover. The possible sources are faecal matter, wood and other plant remains more or less masticated, and saliva. The use of faeces and saliva as a cement for fixing particles of soil may readily be observed in many species of termites engaged in repairing damaged nests or runways; the use of large amounts of faeces in the normal construction of the interior of nests is almost entirely an assumption, though probably correct. In the writer's experience in Trinidad, the only building materials used in large amounts appear to be soil and faecal matter. No evidence has been found to show that wood and other plant remains are used in building until they have passed through the digestive canal of the termites. Some species are reported to use only saliva as a cement, but the use of faeces is probably more general.

Few analyses of the materials in termite nests have been made. The most detailed known to the writer are those of Holdaway (1933) and of Cohen (1933) of mounds of the Australian *Eutermes* (*Nasutitermes*) *exitiosus* Hill. The outer wall was found to contain 50 to 80 per cent. of inorganic matter and the interior of the nest about 5 to 20 per cent. Organic carbon formed 8 to 25 per cent. of the outer wall and 44 to 53 per cent. of the interior. The percentages of cellulose in the oven-dry combustible material in the outer, middle and inner regions of one nest were 5, 7 and 9; of lignin, 24, 30 and 31; and of total pentosans 10, 10 and 8. The ratio of lignin to cellulose was about 4:1, increasing only slightly towards the interior. In a typical wood this ratio is about 1:2. Holdaway interpets these figures as indicating that the lignin in wood is not digested and that most but not all of the cellulose is absorbed; the slight increase in lignin-cellulose ratio towards the interior suggests that material used there has been subjected to more prolonged digestion than in the outer parts of the nest.

It is likely that the above figures are typical of the nests of mound building termites but with great variations in the relative amounts of inorganic matter (mostly soil particles). Other published data on analyses seen by the writer add little to the above information.

The composition of the materials used in construction of covered passages, and in lining galleries in wood, has not been adequately studied. The appearance of these materials as used by *Heterotermes* and *Coptotermes* in Trinidad suggests that they consist largely of soil particles cemented by faeces. Their chemical composition probably resembles that of the outer portions of the nests of *Nasutitermes exitiosus* described by Holdaway and by Cohen, but with a higher proportion of inorganic matter.

The relative fertility of abandoned termite mounds has received much attention, with somewhat conflicting results, due no doubt to differences in the species of termites concerned and the soils in which they work. In parts of Africa certain types of vegetation develop only on the sites of large mounds, which may have profound effects on the aspect of the landscape. It is commonly assumed that termite mounds are rich in organic matter, and this is probably correct in many cases, but Griffith (1938) in Uganda found a lower content of organic matter in mounds (0.83 to 1.49 per cent.) than in the surrounding soil (1.18 to 2.39), and an increase of available inorganic nutrients in certain mounds and a decrease in others. He states that in certain districts cotton makes better growth on termite hills than elsewhere. (Unfortunately the species of termites and the age of their mounds are not stated.) Analyses by Joachim and Kandiah (1940), of earth formed from nests of *Cyclotermes redemanni* in Ceylon, showed in most cases a reduction in organic matter, nitrogen and exchangeable bases as compared with the surrounding soil, but the reverse appears to be true of the nests of *Hypotermes obscuripes* which contain fungus gardens. These authors write "It is the general experience that, in chena lands, crops grow and yield best on termite mounds and immediately around them". Vageler (1933) writes that in grey earth districts in Africa "termite-infested red earths are for the most part considerably richer in plant foods than the surrounding grey soil" and that "In India this special composition of termitaria has been exploited on a large scale and, in some cases, with striking success". Pendleton (1942) states that the increased fertility of mounds in Thailand appears to be due to higher nutrient content, higher pH and better moisture relations. Kalshoven (1941) cites cases of both high and low relative fertility of mounds in the East Indies and emphasizes the need for further researches. It is especially desirable that investigators should record the species of termites concerned, owing to the wide variations in the proportions of organic and inorganic materials used in mound building, in the use of fungus gardens and many other habits.

The accumulation of calcium carbonate in termite mounds (the species not stated) has been reported by Milne (1938) in Tanganyika, Griffith (1938) in Uganda, and Pendleton (1942) in Thailand. Milne writes that in districts with acid soils, where two or more mounds per acre occur, a serious depletion of lime appears to result, as the lime present in the earthy part of the mound represents the equivalent of a heavy agricultural dressing. All analyses made by Pendleton showed a higher percentage of calcium carbonate in

mounds than in the surrounding soil. In two samples from the base of mounds, 31 and 41 per cent. consisted of concretions in which the percentages of calcium carbonate were 35 and 18. The reason of this accumulation of lime in termite mounds appears to be unknown.

Factors in Soil Fertility Affected by Termites

In addition to general effects produced by termites, such as the weathering of soil carried above the surface, the following factors in soil fertility may be discussed individually.

Organic matter, including humus. By promoting the disintegration of vegetable remains the termites contribute largely to the formation of humus. By bringing soil above the surface, and by carrying organic matter underground, they accelerate the incorporation of humus into the soil. On the other hand, many termites may considerably reduce the organic content of the soil by consuming vegetable remains that would otherwise ultimately form humus, and also by feeding directly upon humus in the earth. The net effect of their activities in any area will depend on the ratio between formation and destruction of humus and this ratio may vary widely according to differences in the soil, vegetation and habits of the termites in each locality. Where vegetation is luxuriant it is unlikely that termites ever create a deficiency of organic matter in the soil, but they may well do so in dry areas in Africa where great numbers of termites exist on the dead remains of a somewhat sparse flora. Little attention appears to have been paid to this possibility.

Mineral elements. With the exception of fixed nitrogen, which may perhaps be dissipated to some extent after passing through the digestive tract of termites, all essential mineral elements in their food are no doubt returned to the earth, and the termites probably play an important part in promoting the cycle of nutrient elements in the soil.

Lime content. The accumulation of calcium carbonate in some termite mounds may seriously reduce the lime content of the surrounding soil, as already mentioned. It may also increase the fertility of soil formed by the decay of abandoned mounds.

Soil structure. In most of their work with soil the termites probably tend to improve its structure, especially by promoting its admixture with humus and by burrowing extensively through it. It seems probable that a soil of good structure is produced by the disintegration of termite mounds. The effect of those which ingest large amounts of soil is difficult to assess.

Aeration. In many tropical soils aeration must be greatly facilitated by burrows which penetrate almost every cubic foot to considerable depths. When in use the walls of the tunnels are probably somewhat impermeable to air, being compact and often lined with a cement-like deposit of faeces, but abandoned tunnels are probably efficient in aeration. After the collapse of the walls, spaces for the passage of air remain for some time.

Drainage. Subterranean tunnels and nests, when abandoned, presumably facilitate infiltration of water as they promote aeration. Tunnels in use are probably seldom flooded. Increased drainage due to termites may reduce run-off after heavy rain.

Penetration of roots. The penetration of roots into compact soil may be facilitated by subterranean tunnels. Harris (1936) in Tanganyika writes that their value is "particularly noticeable in the red soils of schist origin, which are often free from stones and pack hard without cracks to a great depth, rendering penetration difficult".

Habitats for epiphytes. In the forests of Trinidad there is an abundant and varied growth of epiphytic plants. The more specialised of these, such as bromeliads, are independent of soil, but the roots of many others are surrounded by large amounts of earthy material, most of which has been brought up by termites. It appears likely that the growth of these plants is promoted by termite activities and that some epiphytes may even be dependent upon them.

Erosion. The harvester termites of the genus *Hodotermes* collect blades of living grass and on African velds they may completely denude the ground in the vicinity of their nests, which may be very numerous. A considerable amount of erosion may result after periods of drought, when the grass is not replaced rapidly enough to maintain a protective cover (Naude, 1934 and Coaton, 1937).

Summary

The following subjects are discussed in some detail: the mode of life of termites in relation to the soil, their feeding habits, the nature of their building materials, and factors in soil fertility which may be affected by their activities. Termites are earth-dwellers to a much greater degree than is generally recognised. In Trinidad very many of them appear to feed like earthworms by ingesting soil; there are few records of this habit from other countries, where little attention has been paid to it. The prodigious activities of termites must have a profound influence on soil, increasing its fertility in some ways but reducing it in others.

The most important activities of termites affecting soil fertility are probably the consumption of dead wood and other plant remains, whereby the formation of humus and the cycle of mineral elements are accelerated, and the movement of soil above the surface, for building nests and covered runways and for lining or filling galleries in wood, thereby exposing soil to weathering and promoting its admixture with humus. Subterranean tunnels, which may

extend through every cubic foot of soil to considerable depths, promote aeration, drainage and penetration of roots. Large termite mounds, when abandoned, may form soil of relatively high fertility, and soil carried high up on tree trunks and branches may favour the growth of certain epiphytic plants.

In dry areas of sparse vegetation it is possible that the amount of organic matter in the soil may be seriously reduced by great numbers of termites feeding on plant remains, including humus already incorporated in the soil. This possibility does not seem to have been investigated. Harvester termites attacking live grasses denude parts of African velds, causing erosion. The accumulation of calcium carbonate in large mounds may result in deficiency of lime in the surrounding soil.

Researches required to elucidate the relations between termites and soil fertility include quantitative investigations on the size of termite populations, the number and dimensions of mounds, the amount of earth brought above the surface, and the extent of subterranean tunnels. Few precise data on these subjects have been recorded. Much work is required also on the chemical composition of termite building materials and on their feeding habits, especially as regards organic matter in the soil.

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CITRUS ROOTSTOCK TRIALS IN THE PUNJAB

An article in the *Indian Jr. of Agr. Sc.*, 12, 1942, 381-99, discusses some preliminary results of a citrus rootstock investigation begun in 1937 at Montgomery, Punjab, to determine the most suitable stocks for sweet orange (Malta), mandarine (sangtra) and grapefruit in that district. The present studies cover only the vegetative phase of the young trees. (a) *Kharna khatta* (*C. karna* Raf) is associated with the most vigorous trees irrespective of scion variety; (b) *Jatti khatti* or rough lemon (*C. limonia* Osbeck) also gives vigour to its scion but to a lesser extent ; (c) *Mitha* or sweet lime (*C. aurantifolia* var. Swingle) is a dwarfing stock ; (d) Nasnaran (*C. japonica* Thunb.) imparts vigour to sweet orange but dwarfs mandarin. *Mokari* citron (*C. medica* L.) imparts vigour to mandarin, but dwarfs sweet orange and grapefruit ; (*e*) grapefruit on *chakotra* or shaddock shows mottled leaves, the cause being not yet determined. Instances are given to show that the vigour of an unworked rootstock is no criterion of its vigour when grafted with certain scion varieties, *e.g.*, the comparatively dwarf *nasnaran* when grafted with sweet orange gives rise to very vigorous trees, whereas the dwarfing *mitha* ungrafted is vigorous and spreading.

OBSERVATIONS ON COTTON STAINERS (*DYSDERCUS SPP.*) AND THEIR HOST PLANTS IN JAMAICA

BY

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Introduction

Cotton stainers of the genus *Dysdercus* are among the most serious pests of cotton, especially in Africa, South America and the West Indies, and are the subject of an extensive literature. In the West Indies there are some ten species, of which *Dysdercus andreae* (L.) and *D. discolor* Walk. are the most important from the economic point of view. Ballou (1), Mumford (6), Myers (7), Pearson (8) and Squire (9) among others have studied cotton stainers in the West Indies. Squire has an unrivalled knowledge of these pests and their host plants in the Lesser Antilles, but apparently never visited Jamaica. In 1942 I spent some eight weeks in the island where I had the opportunity of making some observations on cotton stainers in relation to their host plants.

Importance of Stainers

In Jamaica I had the privilege of discussing various aspects of the cotton stainer problem with Mr. J. B. Hutchinson, Chief Geneticist of the Cotton Research Station in Trinidad, and Mr. W. H. Edwards, Government Entomologist of the Jamaica Department of Science and Agriculture. They were of the opinion that the successful growing of cotton there would be entirely dependent on the control of insect pests, of which the most important are cotton stainers.

Control of stainers can be most successfully achieved either by the destruction of their host plants or by evading the main attack by an adjustment of the time of cotton planting. In either case a knowledge of the stainer host plants and of their distribution, ecology and fruiting phases is essential. Little is known of stainers in relation to their host plants in Jamaica. There may well be a cycle of host plants, such as Squire has described in the Lesser Antilles, which can be broken by the elimination of one plant species.

Species of Stainers

Three species of cotton stainers occur commonly in Jamaica. These are *Dysdercus andreae* (L.), *D. sanguinarius* Stål and *D. mimulus* Hussey. A fourth species, *D. suturellus* (H.-S.), may possibly occur, but if so is extremely rare.

D. andreae is a widely distributed species, ranging from Florida, U.S.A. through the Greater Antilles and the Lesser Antilles as far south as Guadeloupe. *D. sanguinarius* is a Greater Antillean species, occurring in Cuba and the Isle of Pines, Jamaica, Haiti and Puerto Rico. According to Barber (2) and Hussey (4), *D. jamaicensis* Walk. is a synonym of *D. sanguinarius*. *D. mimulus* has a wide geographical distribution, ranging from Texas, Arizona and California, U.S.A. through Mexico and Central America to Panama and from Florida, U.S.A. through the Greater Antilles excluding Puerto Rico. According to Hussey (4), *D. mimus* (Say) in part is a synonym of *D. mimulus*.

I observed many thousands of *D. andreae*, *D. sanguinarius* and *D. mimulus* in Jamaica, but did not see a single individual of *D. suturellus*, which Gowdey (3) mentions as occurring there. I examined a single specimen labelled as this species in the collection of the Jamaica Department of Science and Agriculture, but did not have an opportunity of comparing it with authoritatively determined specimens. This species is known from the U.S.A., the Bahamas, Puerto Rico, Cuba and the Isle of Pines. It may conceivably also occur in Jamaica, but seems to be extremely rare.

Host Plants

There is evidence to show that both the nymphs and adults of cotton stainers require concentrated food rich in proteins, and they obtain this from the developing seeds of plants. According to Squire the staple host plants on which stainers have been observed actively feeding and breeding in the West Indies belong without exception to the families Malvaceae, Sterculiaceae, Bombacaceae and Tiliaceae.

Among the Bombacaceae the silk cotton tree, *Ceiba pentandra* Gaertn., and cork wood, balsa wood or bois flot, *Ochroma pyramidale* Urb., are well known stainer hosts. *Ceiba* is common in Jamaica in the drier xerophytic areas and the fruiting phase occurs from about March to June. This species is capable of supporting very considerable stainer populations during the fruiting period, and is probably the most important stainer host not only in Jamaica but throughout the West Indies. *Ochroma* is common in the lower mountains and in damp situations in Jamaica. It is essentially a tree of secondary growth, and the fruiting phase probably occurs from about April to July.

Among the Sterculiaceae the bastard mahoe or saltfish wood, *Sterculia caribaea* R. Br., *S. apetala* Karst., and cola, *Cola acuminata* Schott and Endl., are important stainer hosts. *Sterculia* is rare in Jamaica, grows in heavy rainfall areas and the fruiting phase probably occurs from about September to December. *Cola* is common in heavy rainfall areas, being a shade-loving tree often associated with cacao, and the fruiting period probably extends from June to September.

Among the Malvaceae annual and perennial cottons are seriously attacked by stainers. According to Hutchinson (5) the perennial cotton, *Gossypium hirsutum* var. *marie-galante*, is indigenous to Jamaica. It is a cotton of the xerophytic scrub lands, and is most common and variable in the dry southern plains. The perennial and annual Sea Island cottons, *G. barbadense* L. and *G. barbadense* var. *braziliense*, have been introduced into Jamaica, and the perennial forms have become established in the moister and more mesophytic areas.

Apart from the cottons, the most important Malvaceous stainer hosts are seaside mahoe, cork tree or John Bull tree, *Thespesia populnea* Sol., seaside mahoe, *Hibiscus tiliaceus* L., blue or mountain mahoe, *H. elatus* Sw., and various herbaceous weeds. In Jamaica *Thespesia* is common around the coast and fruits perennially, *H. tiliaceus* is a common sea-shore species and *H. elatus* is one of the most valuable timber trees. The latter is essentially a montane species, and is being planted extensively at the present time in the re-afforestation of mountainous areas. The fruiting period probably extends from about March to June. The status of this tree as a stainer host in Jamaica is unknown. Malvaceous weeds of various genera are well known to be stainer hosts. Such weeds are very common in the island, fruit perennially and support large stainer populations.

Myers (7) states that in Cuba the most important host plants of *D. andreae* are *Thespesia populnea*, *Hibiscus elatus* and *Sterculia apetala*, and *Abutilon* sp. and *Sida* sp. are of less importance. The host plants of *D. mimulus* are herbaceous rather than arboreal, the most important being *Sida* sp. (near *cordifolia* L.) and *Abutilon* sp. Myers states that the majagua, *H. elatus*, is a favourite host plant of *D. andreae*. Referring to this host plant, he observes "Near the beginning of February the freshly opened fruits were hidden beneath scarlet masses of copulating adults, sucking the juices of the young seeds, which falling to the ground below, proved a vast attraction to the myriads of young nymphs, running in all directions over the surface and on the lower plants, but mounting no higher than a foot. No nymphs were observed on the fruits upon the tree, and the overwhelming majority were on the ground itself. Here and there were little red clusters of living bugs, chiefly nymphs, forming balls up to an inch in diameter. These centred and swirled round dropped seeds of the majagua."

Wolcott (10) records that in Puerto Rico, apart from cotton, the host plants of *D. andreae* are *Ceiba pentandra*, *Thespesia populnea*, *Montezuma speciosissima* Ses. and Moc., *Abutilon hirtum* Sweet and *Sida* sp. The host plants of *D. sanguinarius*, apart from cotton, are *T. populnea*, *M. speciosissima* and *Sterculia apetala*.

Detailed Records

Records of cotton stainers and their host plants were made in Jamaica from 20th June to 14th August, 1942, and, apart from a visit to Port Antonio on the North Coast, were confined to the Liguanea Plain, the Port Royal Mountains and the Blue Mountains. The Liguanea Plain extends from Kingston to the foothills of the Port Royal Mountains. The annual rainfall varies from 30 to 35 inches in the vicinity of Kingston to from 40 to 50 inches at the base of the foothills. The vegetation comprises xerophytic scrub including acacias and mesquite, typical of the arid southern plains. Observations were made at Hope (600 feet).

The Port Royal Mountains extend as a ridge rising abruptly to the north of the Liguanea Plain and separated from the Blue Mountains by the deep-cleft Yallahs Valley. They reach an altitude of about 4,000 feet, and consist of metamorphic shales and conglomerates with white limestone. This limestone is much honeycombed, and the conspicuous and highly fertile red earth, occurring in depressions and crevices in the rock, represents the insoluble residue after the solution of the calcium carbonate by the action of rain-water. The annual rainfall varies from about 50 to 70 inches. The vegetation consists of xerophytic scrub and secondary xerophytic woodland, often on seriously eroded slopes abandoned by earlier cultivation. Observations were made at Flamstead (3,800 feet).

The Blue Mountains occupy the eastern end of Jamaica, extending as a range from east to west and culminating in Blue Mountain Peak (7,360 feet). They consist of metamorphic shales and conglomerates with white honeycomb limestone, and are similar in formation to the Port Royal Mountains. On the southern slopes the annual rainfall varies from 90 to 100 inches and on the northern ones exceeds 100 inches. Up to about 5,000 feet the vegetation consists of secondary mesophytic woodland on steep hillsides, formerly cleared and extensively cultivated, and now abandoned. Serious soil erosion and depletion of soil fertility has resulted on the more exposed slopes. Above about 5,000 feet the vegetation comprises typical upper montane rain forest with elfin woodland on the exposed summits. Observations were made at Hardware Gap (4,080 feet), Silver Hill Gap (3,500 feet), Clydesdale (3,500 feet) Cinchona (4,950 feet) and Catherine's Peak, (5,050 feet).

Few opportunities were afforded for the examination of arboreal stainer hosts. At the time observations were made the fruiting phase was over in *Ceiba pentandra* and *Hibiscus elatus*. Except for brief notes on *Thespesia populnea* and *H. elatus*, no records were made on woody hosts, but were confined to herbaceous weeds belonging to the Malvaceae. All records are of actual host plants, on which stainers were observed actively feeding and breeding in considerable numbers, nymphs of all instars and adults *in copula* being invariably present.

Stainers were recorded on the following Malvaceous weeds: *Sida acuta* Burm., *S. rhombifolia* L., *Urena lobata* L., *Malvastrum coromandelianum* Garcke and *Wissadula periplocifolia* Presl. *S. acuta*

is an extremely variable species. Pedicels of the fruits may be shorter than the petioles of the leaves or twice their length. The leaves are very variable, being 2 to 10 cm. in length. They vary with the age of the plant as well as with the situation, being narrower on older plants. *S. rhombifolia* is also a variable species. Pedicels are longer than in *S. acuta*, being 1 to 4 cm. in length and jointed above the middle. The leaves are very variable, being 1 to 7 cm. in length, and show the same variability as *S. acuta* in relation to the age of the plant as well as the situation. In Jamaica lowland forms of *S. rhombifolia* appear to have short pedicels and broad leaves, while montane forms have long pedicels and narrow leaves.

At Hope the important stainer hosts were *S. acuta, S. rhombifolia, M. coromandelianum* and *W. periplocifolia. Dysdercus andreae* and *D. mimulus* were observed on *S. rhombifolia,* and *D. andreae* on *S. acuta, M. coromandelianum* and *W. periplocifolia.* The numbers of *D. andreae* were truly astounding. I have never previously seen such myriads of stainers on any host plant in the West Indies. Immense numbers of nymphs of all instars as well as adults *in copula* were noted on *M. coromandelianum.* Adults *in copula* were so abundant on *W. periplocifolia* that plants appeared red from a distance and were weighed down by the great masses of stainers on the fruits. Adults, often in considerable numbers, were commonly found at night attracted to lights.

At Port Antonio *S. rhombifolia* and *Thespesia populnea* were present. *T. populnea,* in common with the herbaceous Malvaceae, flowers and fruits perennially, and considerable numbers of fruits were on the trees. No stainers were observed on either host plant.

At Flamstead the important stainer hosts were *S. rhombifolia* and *U. lobata.* Both plants were very abundant on formerly cultivated but now abandoned lands. *D. andreae* and *D. mimulus* were observed on *S. rhombifolia. D. andreae, D. sanguinarius* and *D. mimulus* were observed on *U. lobata.* It is interesting to note that *D. mimulus* was abundant with some *D. andreae* and *D. sanguinarius* on *U. lobata* growing in the sun in a dry environment on open hillsides. *D. mimulus* was completely absent and *D. sanguinarius* abundant with some *D. andreae* on the same plant growing nearby in the shade under woodland canopy in a damp situation. This suggests that *D. mimulus* prefers a dry, open and sunny environment. A few small trees of *Hibiscus elatus,* with dry dehisced fruits containing seeds, were examined. No stainers were observed on this host plant.

At Hardware Gap *S. rhombifolia* and *U. lobata* were present. No stainers were observed on *S. rhombifolia. D. andreae* and *D. sanguinarius* were noted on *U. lobata.* Some young trees of *H. elatus* without fruits were examined, but no stainers were seen.

At Clydesdale *S. rhombifolia* and *U. lobata* were present. No stainers were seen on *S. rhombifolia. D. sanguinarius* and *D. mimulus* were noted on *U. lobata.*

At Silver Hill Gap, Cinchona and Catherine's Peak *S. rhombifolia* and *U. lobata* were present. No stainers were observed.

Summary

1. The most important potential pests of cotton in Jamaica are cotton stainers (*Dysdercus* spp.).

2. *Dysdercus andreae* (L.), *D. sanguinarius* Stål and *D. mimulus* Hussey are the common species of stainers in Jamaica. *D. suturellus* (H.-S.) may occur as a rare species.

3. *Ceiba pentandra* Gaertn. is capable of supporting very considerable stainer populations and is probably the most important stainer host. Other important woody hosts include *Ochroma pyramidale* Urb., *Cola acuminata* Schott and Endl., *Thespesia populnea* Sol., *Hibiscus elatus* Sw. and *H. tiliaceus* L.

4. Malvaceous weeds fruit perennially, support large stainer populations and are important stainer hosts. These herbaceous hosts include *Sida acuta* Burm., *S. rhombifolia* L., *Urena lobata* L., *Malvastrum coromandelianum* Garcke and *Wissadula periplocifolia* Presl.

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CONTROL MEASURES AGAINST SWOLLEN SHOOT VIRUS DISEASE OF CACAO

BY

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Swollen-shoot disease of cacao (*Theobroma*) has been described in previous papers (1, 3, 4, 5, 7). Subsequent unpublished work has proved that the disease is insect-transmitted,* and it has been established that the infection does not spread when infected trees are enclosed in insect-proof cages. It is most unlikely that control of the insect vectors will become a practical measure, and therefore elimination of trees carrying the virus is the only possible alternative means of control. This paper gives the results of control measures at the Central Cocoa Research Station at Tafo (7), near the edge of the most heavily infected locality. The results justify the eradication campaign on which the Gold Coast Department of Agriculture has embarked to prevent the spread of Swollen-shoot disease to districts believed to be uninfected. The fringes of the known infected areas are surveyed, and as isolated outbreaks are discovered, they are treated by cutting down and stumping all infected trees, together with a ring of apparently healthy trees ; compensation for the latter only is paid to the owners. All strains of the virus are thus treated ; at Tafo only the most virulent strain occurs naturally, and is the only one considered in this paper.

Rate of Spread

There are two types of spread, which must be explained before considering the control of the disease. The more obvious is the gradual enlargement of an outbreak by the infection of trees adjacent to those already diseased. This spread is slow, but steady and relentless, seldom leaving any healthy trees inside the diseased area. The figures in Table I show the rate of this type of spread in three farms which have been longest under observation without any form of treatment. Trees were not removed until completely dead. The rate of spread on areas which have come under observation more recently indicates that the figures in Table I are typical for outbreaks consisting of about one hundred infected trees and a perimeter of forty healthy trees. However, the larger the diseased area, the more healthy trees on the perimeter are in contact with infected trees and consequently the greater the number of new infections each month.

This comparatively slow spread is not alarming unless it is considered in conjunction with the second type of dispersal—the appearance of new scattered outbreaks some distance from the first or main outbreak. These outbreaks enlarge like the first, the rate of spread accelerating until the farm is destroyed. It seems probable that these subsidiary outbreaks originated from the first (by the dispersal of vectors) but it is possible that they are fresh infections from an alternative host-plant, or other source from which the first infection came. Although their position (*see* plan) indicates a random scattering, the subsidiary outbreaks tend to become fewer as the distance from the main

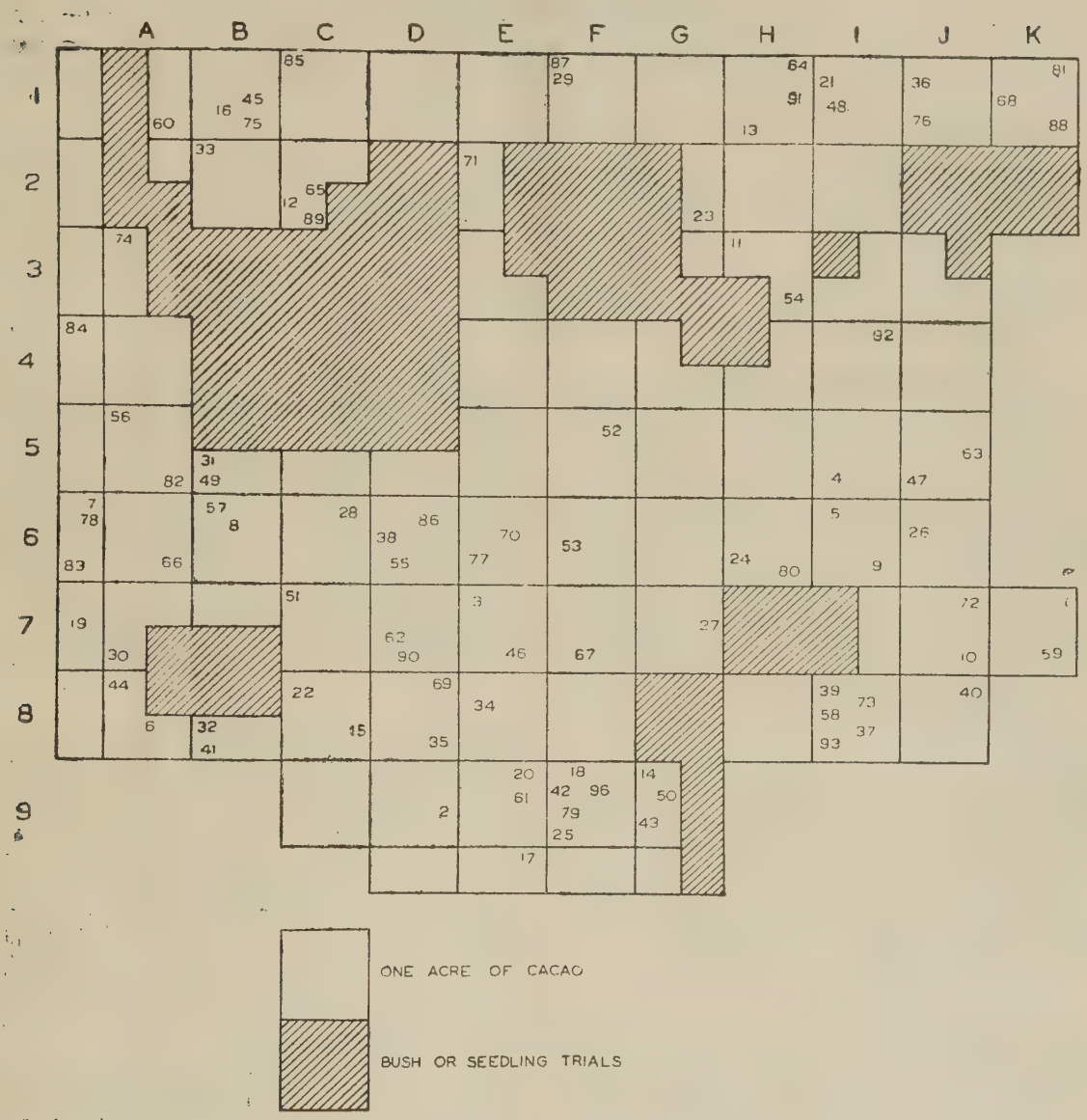
TABLE I

Rate of spread of untreated outbreaks—No. of trees showing symptoms for the first time in each month

Outbreak.	Year.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
A ...	1940 ...						14		—	5	1	1	1
	1941 ...	4	—	12	10	15	6	3	—	2	2	Treated	
B ...	1940 ...						2			1	1	1	2
	1941 ...	1	—	3	5	2	4	—	1	1	1	1	—
	1942 ...	—	2	3	1	3	2	7	5	0	2	—	1
	1943 ...	1	—	4									
C ...	1942 ...	—	—	2	4	7	1	—	1	—	5	4	1
	1943 ...	—	—	5									

* In unpublished reports G. S. Cotterell, Entomologist of the Department of Agriculture, has described successful transmissions under experimental conditions with certain Mealy bugs (*Coccidae*), a Psyllid (*Mesohomotoma tesmanni* Aulm) and an Aphid (*Toxoptera aurantii* Boyc). All of these insects are common and widespread on cacao in the Gold Coast.

PLAN OF CENTRAL COCOA RESEARCH STATION



Position of Outbreaks (Numbered in Order of Discovery)

outbreak increases. Until more is known about the alternative host-plants of the virus, the origin of all outbreaks must remain speculative. In Tables 3, 4 and 5, figures are given of the number of new outbreaks occurring each month on Tafo station, but it should be remembered that these numbers would almost certainly have been much larger in the absence of the control measures to be described.

The best estimate of the destructive powers of the disease, when both methods of spread are allowed to take their natural course, can be obtained from the study of an isolated outbreak at Apedwa, 11 miles south-west of Tafo. This area has been watched since 1937, when it was surveyed by Mr. F. C. Deighton, then Acting Plant Pathologist. A windbreak of *Cassia siamea*, planted in 1938 by Mr. E. F. S. Shepherd, then Plant Pathologist, has failed to check the spread of the disease, which is also independent of overhead shade. Table II gives the actual distance of spread in the past four years. The area infected in 1937 was approximately 1,000 square yards with a perimeter of about 50 infected trees. In 1943 it covers at least 20,000 square yards, excluding a number of scattered outbreaks which have started from it.

TABLE II

Rate of spread (in feet) of Apedwa outbreak

	North	North-East	East	South-West	West	North-West
Oct., 1937 to April, 1940	10	30	13	60	—	—
Oct., 1937 to Jan., 1941	132	84	48	66	36	45
Oct., 1937 to April, 1942	159	128	123	166	51	72
Oct., 1937 to Jan., 1943	264	230	258	234	156	141

Note.—South and South-east bounded by stream and bush.

Routine Control Measures

The investigations to be described involved about 70 acres of cacao, varying in age from 5 to 30 years (7). This cacao had been planted by farmers in the local manner—irregular close spacing (about 5 ft. apart) followed by gradual thinning or repeated supplying of vacancies until a density of about 600 per acre is reached at 15 years, and 300 per acre at 25 years. It is shaded by a large variety of indigenous forest trees (8) at a density averaging 25 per acre. With the exception of 46 trees, the cacao is all the true-breeding "Amelonado" variety which has been wrongly called *Theobroma leiocarpa* Bern. in previous publications (2).

The first outbreak of Swollen-shoot on the station was discovered in December, 1938, and further outbreaks were found continuously from May, 1939 onwards. By the end of 1939 the virus nature of the disease had been established (3) and it was decided to start an eradication campaign in February, 1940, when 11 outbreaks were known on the station, totalling 55 infected trees.

1940-41 Results

The first attempts to stop the spread of the disease consisted of cutting down and stamping all trees showing the characteristic swellings. This treatment was a complete failure, like the 1936 attempt at field contro (6), and for the same reasons. Twig swellings are extremely difficult to find on a mature tree in the early stages of infection, because they are often concealed by foliage; swellings large enough to be detected at a distance are not usually produced until the tree has been infected for nearly a year. Consequently outbreaks were seldom discovered until several trees had become infected. The discovery in transmission experiments that leaf-mosaic is a reliable symptom greatly facilitated diagnosis, and consequently the treatment became more effective. The spread of the disease was stopped in some of the small outbreaks, usually those of less than six trees. Altogether, 16 outbreaks were treated successfully, while 12 continued to spread.

There is no doubt that the efficiency of the treatment improved with practice in diagnosis. Even after mosaic became a recognised symptom, many trees were left which would now be recognised without hesitation as infected. Nevertheless, it became evident after a year that the disease could not be controlled effectively by the removal of obviously diseased trees alone. Transmission experiments had shown a lag of about three months between infection and the appearance of symptoms. The frequent occurrence of symptoms on adjacent trees only a month after the removal of all those obviously infected indicated that a number of apparently symptomless trees in contact with those showing mosaic were usually infected.

1941-42 Results

In February 1941, when there were 28 outbreaks on the station, the treatment was made more drastic by the removal of a ring of apparently healthy trees from 24 treated outbreaks, leaving four outbreaks as controls. Except on these four, subsequent treatment always involved the removal of infected trees and of the surrounding ring of symptomless trees, together with any other more remote trees in contact with an infected tree. It can be seen in Table IV that this treatment was more effective in reducing tree-to-tree spread of infection, which continued unchecked on the control plots. As the object of this treatment was to eradicate the disease from the station, and not merely to experiment, a ring of symptomless trees was removed from the four control plots five months later. The reason for the removal of these apparently healthy trees can be appreciated when one considers the lag of several months occurring between artificial infection and the appearance of symptoms; if this is taken in conjunction with the almost continuous spread, and the difficulty of finding the earliest signs of mosaic in the foliage of large trees, the destruction of a ring of symptomless trees appears even more necessary for control.

After May 1941 the search for new outbreaks was put on a systematic basis—each plot was inspected every month by an Overseer. Previously, outbreaks had been discovered more or less accidentally; although all the staff had been looking for symptoms, their excursions usually follow the paths.

TABLE III

STATION OUTBREAKS 1940-41

Distribution of infected trees for first year of treatment

(Destroyed without contacts)

Outbreak No.	Date found	1940									1941			Spread
		Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	
1	Feb., 1939	1	—	—	7	—	1	—	—	—	1	—	—	Continues.
2	June, 1939	8	—	—	11	2	—	—	1	—	—	1	—	Continues.
3	Sept., 1939	1	—	—	7	12	—	—	1	2	—	—	—	Continues.
4	Sept., 1939	5	—	—	2	2	—	4	—	—	—	3	—	Continues.
5	Sept., 1939	8	—	1	—	1	—	5	—	7	1	2	1	Continues.
6	Dec., 1939	4	—	2	—	—	—	—	—	—	—	—	—	Stopped.
7	Dec., 1939	7	—	—	16	2	1	—	—	—	—	2	—	Continues.
8	Dec., 1939	16	—	—	41	3	6	7	—	3	14	6	3	Continues.
9	Dec., 1939	1	—	—	—	—	—	—	—	—	1	—	—	Stopped.
10	Dec., 1939	3	—	—	6	—	2	2	1	1	1	1	—	Stopped.
11	Mar., 1940	1	—	—	—	—	—	—	—	3	—	1	2	Continues.
12	April, 1940	—	2	—	—	—	—	—	—	—	—	—	4	Stopped.
13	May, 1940	—	—	3	—	—	—	—	—	—	—	—	—	Stopped.
14	July, 1940	—	—	—	—	32	1	—	2	2	11	2	2	Continues.
15	July, 1940	—	—	—	—	25	—	—	—	1	—	1	—	Stopped.
16	July, 1940	—	—	—	—	8	1	—	—	—	—	1	—	Stopped.
17	July, 1940	—	—	—	—	2	—	—	—	—	—	—	—	Stopped.
18	July, 1940	—	—	—	—	2	—	—	—	1	1	—	1	Stopped.
19	Aug., 1940	—	—	—	—	—	3	—	—	—	—	—	—	Stopped.
19	Sept., 1940	—	—	—	—	—	—	6	—	—	—	1	—	Stopped
21	Oct., 1940	—	—	—	—	—	—	—	28	5	4	3	3	Continues.
22	Oct., 1940	—	—	—	—	—	—	—	1	—	—	—	—	Stopped.
23	Oct., 1940	—	—	—	—	—	—	—	4	—	—	1	—	Stopped.
24	Oct., 1940	—	—	—	—	—	—	—	11	—	—	—	1	Stopped.
25	Nov., 1940	—	—	—	—	—	—	—	—	6	—	—	—	Stopped.
26	Nov., 1940	—	—	—	—	—	—	—	—	2	—	—	—	Continues.
27	Nov., 1940	—	—	—	—	—	—	—	—	1	2	—	—	Stopped.
28	Feb., 1941	—	—	—	—	—	—	—	—	—	—	—	4	Continues.
Total trees		55	2	6	90	91	15	24	49	34	36	25	21	448 } Year totals
Total active outbreaks		11	1	3	7	11	7	5	8	12	9	13	9	28 } Year totals
Total new outbreaks		1	1	1	—	5	1	1	4	3	—	—	1	18 } Year totals

With new infections appearing each month, apparently at random, it became obvious that some trees on the edge of an old outbreak might become infected from an outside source and would be counted as the spread of the old outbreak instead of the initiation of a new one. Again arguing from graft-transmission experiments in which symptoms usually appear within three, and always within 5 months after infection, it was decided to regard as a new outbreak any infection appearing after an old outbreak had been free for six months. On this assumption, by March 1942, 39 outbreaks had been cleared up, and only 4 were still spreading.

1942-43 Results

The rogueing of infected trees during 1940 and 1941 can be regarded as the elimination of the Swollen-shoot virus from the station cacao. This did not reduce the number of new outbreaks, which are regarded as coming either from infected cacao outside the station boundaries through the agency of insects, or from alternative hosts of the virus among the forest trees growing in the station cacao plots. Whatever their origin, it will be difficult if not impossible to prevent such new infections, and their occurrence during 1942-43 may indicate the minimum annual loss to be expected if the present control measures are continued. The increase in the number of new outbreaks from ten in 1939 to 50 in 1942 is far from encouraging, indicating as it does that the infection is rapidly becoming more concentrated in the Tafo area. Had each of these new outbreaks been allowed to spread unchecked, most of the station cacao would by now have been devastated.

An essential part of this control is the tree-to-tree search for symptoms. One trained observer was engaged to spend all his time walking through the plots at a pace which enabled him to survey the whole 70 acres in one month ; thus every tree

TABLE IV

STATION OUTBREAKS 1941-42

Distribution of infected trees for second year of treatment

(Destroyed with contacts)

Outbreak No.	Date found	1941										1942		Spread
		Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Jan.	Feb.	
1	Feb., 1939	—	—	1	—	—	—	—	—	—	—	—	—	Stopped.
2	June, 1939	—	—	1	—	—	—	—	—	—	—	—	—	Stopped.
3	Sept., 1939	—	1	—	—	3	—	—	—	—	—	—	—	Stopped.
*4	Sept., 1939	**1**	**1**	—	**1**	6	—	—	—	—	—	—	—	Stopped.
*5	Sept., 1939	—	—	**2**	—	3	—	—	—	—	—	1	—	Continues.
7	Dec., 1939	—	—	—	—	1	—	—	—	—	—	—	—	Stopped.
8	Dec., 1939	—	—	8	4	9	—	2	—	—	—	—	—	Stopped.
11	Mar., 1940	—	—	4	1	4	—	—	—	—	—	—	—	Stopped.
14	July, 1940	—	—	5	—	5	—	—	—	—	—	—	—	Stopped.
*21	Oct., 1940	**1**	**5**	**12**	**3**	12	—	—	—	—	—	—	—	Stopped.
*26	Nov., 1940	—	**1**	—	—	3	—	—	—	—	—	—	—	Stopped.
28	Feb., 1941	—	—	—	1	—	—	—	—	—	—	—	—	Stopped.
29	April, 1941	—	3	—	—	—	—	—	—	—	—	—	—	Stopped.
30	April, 1941	—	3	—	—	1	—	—	—	—	—	—	—	Stopped.
31	April, 1941	—	5	—	—	3	—	—	—	—	—	—	—	Stopped.
32	April, 1941	—	3	—	—	—	—	—	—	—	—	—	—	Stopped.
33	May, 1941	—	—	3	—	—	—	—	—	—	—	—	—	Stopped.
34	May, 1941	—	—	1	—	—	—	—	—	—	—	—	—	Stopped.
35	May, 1941	—	—	1	—	—	—	—	—	—	—	—	—	Stopped.
36	June, 1941	—	—	—	4	—	—	—	—	—	—	—	—	Stopped.
37	July, 1941	—	—	—	—	7	—	—	—	—	—	—	—	Stopped.
38	Aug., 1941	—	—	—	—	—	3	—	—	—	—	—	—	Stopped.
39	Aug., 1941	—	—	—	—	—	3	—	—	—	—	—	—	Stopped.
40	Oct., 1941	—	—	—	—	—	—	—	1	—	—	—	—	Stopped.
41	Dec., 1941	—	—	—	—	—	—	—	—	—	1	—	—	Continues.
42	Jan., 1942	—	—	—	—	—	—	—	—	—	—	1	—	Continues.
43	Jan., 1942	—	—	—	—	—	—	—	—	—	—	2	—	Continues.
Total trees		2	22	38	14	57	6	2	1	—	1	4	—	147 } Year totals
Total active Outbreaks		2	8	10	6	12	2	1	1	—	1	3	—	27 } Year totals
Total new Outbreaks		—	4	3	1	1	2	—	1	—	1	2	—	15 } Year totals
Total symptomless contact trees destroyed														420

* Black numbers represent infected trees removed without contacts.

had at least a casual glance each month and suspicious-looking trees were inspected carefully. Infected trees with their complement of symptomless neighbours were removed at once.

The figures in Table V show that this routine revealed most of the new outbreaks when the infection was confined to a few trees. Treatment was then effective in eradicating the disease from all but 3 of the 75 outbreaks treated more than six months previously, while the average number of trees infected at the time each outbreak was discovered fell from nearly 8 in 1940 to 2 in 1942-43 (Table VI).

The total number of infected trees found on the station fell from nearly 400 in 1940 to 133 in 1942-3 in spite of the increase in the number of outbreaks discovered.

From the 1940 records it appears that some outbreaks of six trees or less can be controlled without the removal of any apparently healthy trees. Now that the majority of outbreaks are found before they pass the two-tree stage, an attempt will be made to reduce the loss of trees by rogueing such small outbreaks without removing any symptomless trees.

Experimental Control Measures

The failure of one rogueing with one row of contacts to stop the spread of large outbreaks suggested that insect vectors were being scattered from infected trees during the felling operations. Spraying with nicotine solution * was in use in the large-scale treatment of outbreaks in native farms but was not increasing the efficiency of the treatment to any obvious extent. An experiment was started on native farms adjoining the station to test practicable improvements of the routine measures already described. Six treatments were applied each with six replications.

* Forty per cent. Nicotine Sulphate at a concentration of 1 in 1,500.

TABLE V

Distribution of infected trees for third year of treatment

(Destroyed with contacts)

Outbreak No.	Date found	1942 Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1943 Jan.	Feb.	Spread
5 ...	Sept., 1939 ...	2	—	—	—	—	—	—	—	—	—	—	—	Stopped.
41 ...	Dec., 1941 ...	—	—	3	—	—	—	—	—	—	—	—	—	Stopped.
42 ...	Jan., 1942 ...	2	—	—	—	1	2	—	—	—	—	—	—	Stopped.
43 ...	Jan., 1942 ...	—	—	—	1	—	—	—	—	—	—	—	—	Stopped.
44 ...	Mar., 1942 ...	1	—	—	—	—	—	—	—	—	—	—	—	Stopped.
45 ...	Mar., 1942 ...	1	—	—	—	—	—	—	—	—	—	—	—	Stopped.
46 ...	Mar., 1942 ...	2	—	—	—	—	—	—	—	—	—	—	—	Stopped.
47 ...	Mar., 1942 ...	2	1	—	1	—	—	—	—	—	—	—	—	Stopped.
49 ...	Mar., 1942 ...	2	—	3	—	1	—	—	1	1	—	—	—	Stopped.
49 ...	Mar., 1942 ...	2	—	—	—	—	—	—	—	—	—	—	—	Stopped.
50 ...	April, 1942 ...	—	2	—	—	—	—	—	—	—	—	—	—	Stopped.
51 ...	April, 1942 ...	—	1	—	—	—	—	—	—	—	—	—	—	Stopped.
52 ...	April, 1942 ...	—	1	—	—	—	—	—	—	—	—	—	—	Stopped.
53 ...	April, 1942 ...	—	1	—	—	—	—	—	—	—	—	—	—	Stopped.
54 ...	April, 1942 ...	—	1	—	—	—	—	—	—	—	—	—	—	Stopped.
55 ...	April, 1942 ...	—	2	—	—	—	—	—	—	—	—	—	—	Stopped.
56 ...	May, 1942 ...	—	—	1	—	—	—	—	—	—	—	—	—	Stopped.
57 ...	May, 1942 ...	—	—	2	—	—	—	—	—	—	—	—	—	Stopped.
58 ...	May, 1942 ...	—	—	1	—	1	—	—	—	—	—	—	—	Stopped.
59 ...	May, 1942 ...	—	—	3	1	—	—	—	1	—	—	—	—	Stopped.
60 ...	May, 1942 ...	—	—	1	—	—	—	—	—	—	—	—	—	Stopped.
61 ...	June, 1942 ...	—	—	—	1	—	—	—	—	—	—	—	—	Stopped.
62 ...	June, 1942 ...	—	—	—	1	—	—	—	—	—	—	—	—	Stopped.
63 ...	June, 1942 ...	—	—	—	1	—	—	—	—	—	—	—	—	Stopped.
64 ...	June, 1942 ...	—	—	—	2	—	—	—	—	—	—	—	—	Stopped.
65 ...	June, 1942 ...	—	—	—	3	—	—	—	—	—	—	—	—	Stopped.
66 ...	July, 1942 ...	—	—	—	—	9	—	—	—	—	—	—	—	Stopped.
67 ...	July, 1942 ...	—	—	—	—	1	—	—	—	—	—	—	—	Stopped.
68 ...	July, 9142 ...	—	—	—	—	17	—	—	5	—	—	3	—	Continues.
69 ...	Aug., 1942 ...	—	—	—	—	—	1	—	—	—	—	—	—	Stopped.
70 ...	Aug., 1942 ...	—	—	—	—	—	1	—	—	—	—	—	—	Stopped.
71 ...	Aug., 1942 ...	—	—	—	—	—	4	—	—	—	—	—	—	Stopped.
72 ...	Aug., 1942 ...	—	—	—	—	—	2	—	—	—	—	—	—	Stopped.
73 ...	Sept., 1942 ...	—	—	—	—	—	—	1	—	—	—	1	1	Continues.
74 ...	Oct., 1942 ...	—	—	—	—	—	—	—	1	—	—	—	—	Stopped.
75 ...	Oct., 1942 ...	—	—	—	—	—	—	—	1	—	—	—	—	Continues.
76 ...	Nov., 1942 ...	—	—	—	—	—	—	—	—	2	—	—	—	Uncertain.
77 ...	Nov., 1942 ...	—	—	—	—	—	—	—	—	1	—	—	—	Uncertain.
78 ...	Nov., 1942 ...	—	—	—	—	—	—	—	—	1	—	—	—	Uncertain.
79 ...	Nov., 1942 ...	—	—	—	—	—	—	—	—	1	—	—	—	Uncertain.
80 ...	Dec., 1942 ...	—	—	—	—	—	—	—	—	—	2	—	—	Uncertain.
81 ...	Dec., 1943 ...	—	—	—	—	—	—	—	—	—	1	—	—	Uncertain.
82 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	3	—	Uncertain.
83 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	1	—	Uncertain.
84 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	1	—	Uncertain.
85 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	1	—	Uncertain.
86 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	2	—	Uncertain.
87 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	4	—	Uncertain.
88 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	1	—	Uncertain.
89 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	1	—	Uncertain.
90 ...	Jan., 1943 ...	—	—	—	—	—	—	—	—	—	—	1	—	Uncertain.
91 ...	Feb., 1932 ...	—	—	—	—	—	—	—	—	—	—	—	4	Uncertain.
92 ...	Feb., 1943 ...	—	—	—	—	—	—	—	—	—	—	—	1	Uncertain.
93 ...	Feb., 1943 ...	—	—	—	—	—	—	—	—	—	—	—	1	Uncertain.
Total trees ...	...	14	9	14	11	30	10	1	9	6	3	19	7	133 Year totals
Total active Outbreaks	...	8	7	7	8	6	5	1	5	5	2	11	4	54 Year totals
Total new Outbreaks	...	6	6	5	5	3	4	1	2	4	2	9	3	50 Year totals
		Total symptomless contact trees destroyed ...												385

TABLE VI

Summary of four years results

Period (Mar.-Feb.)	All Active Outbreaks			New Outbreaks Only		
	Total		Mean per Outbreak	Total		Mean per Outbreak
	Active outbreaks	Infected trees	No. of trees during year	New outbreaks	No. trees 1st infection	No. trees at 1st discovery
1939-40	10	54	5.4	10	Incomplete diagnosis	
1940-41	28	394	14.1	18	141	7.8
1941-42	27	147	5.4	15	41	2.7
1942-43	54	133	2.4	50	101	2.0

TABLE VII

Experimental treatments

Treatment	No. of infections treated	No. clear for six months after first treatment	No. of infections found after treatment					
			1942				1943	
			Mar.	June.	Sept.	Dec.	Mar.	Total
Rogue infected and one ring of healthy trees	Plots 6	6	2	2	1	3	—	8
	Trees 26		4	4	1	4	—	13
Rogue infected and one ring of healthy trees with *burning*	Plots 6	2	5	4	1	0	—	10
	Trees 27		11	11	2	0	—	24
Rogue infected and one ring of healthy trees with *spraying*	Plots 6	3	3	1	3	1	1	9
	Trees 555		5	2	6	1	3	17
Rogue infected and two rings of healthy trees	Plots 6	4	2	4	2	2	—	10
	Trees 103		2	17	5	7	—	31
Rogue infected and two rings of healthy trees with *burning*	Plots 6	2	3	4	2	0	1	10
	Trees 105		8	6	5	0	2	21
Rogue infected and two rings of healthy trees with *spraying*	Plots 6	5	2	2	1	0	1	6
	Trees 148		5	7	3	0	5	20

In an attempt to control the vectors known at that time two methods were adopted :—
(1) Spraying with nicotine solution* before and during the felling of infected trees, including a 20-yard perimeter round the outbreak and (2) scorching all leaves and green wood immediately after felling.

To cover the time lag between infection and the appearance of symptoms, it was considered impracticable to destroy more than two rows of symptomless trees around an outbreak. The treatments therefore read as in Table VII column 1. The plots were inspected each month, and infected trees were removed promptly, the treatment being that which was applied originally to the plot in which they were found.

A number of complicating factors must be considered in the interpretation of these results. A sufficiently large number of outbreaks of the same size cannot be found near together for comparison, and the success of control measures appears to be inversely proportional to the extent of the outbreak. Each treatment was replicated six times, but as shown in column 2 of Table VII, the number of infected trees was variable for each treatment, and even more variable for plots. The comparative efficiency of rogueing alone (Treat. A) is almost certainly due to the

* Forty per cent. Nicotine Sulphate at a concentration of 1 in 1,500.

relatively small size of the outbreaks given this treatment. The figures in Table VII column 4 include all infected trees found on the perimeter of the treated areas during 15 months after the first attempt at control. Some of these infected trees are probably reinfections from an outside source, judging from the long interval between treatment and the appearance of symptoms.

The experiment demonstrates that none of the treatments is likely, in one operation, to succeed in eliminating the virus completely from extensive areas of infection. Spraying appears to be more effective than burning, but since repeated treatment is usually necessary, it seems very doubtful whether the added efficiency is commensurate with the cost (about 10/- per acre). The same may be said about the removal of two, instead of one, ring of symptomless trees. If complete control cannot be obtained at the first attempt, it is more economical to remove one ring of apparently healthy trees, and regard subsequent infections as small outbreaks which are readily eliminated by these control measures.

Although the spread of individual outbreaks can be stopped effectively, it is clear that this exerts little or no check on the formation of new outbreaks. As the concentration of infection increases in farms around Tafo, the frequency with which fresh outbreaks develop on the station will probably rise. The present control measures cannot be expected to do more than delay the ruination of the cacao, in the hope that replanting with a resistant variety may eventually keep pace with the destruction.

Summary and Conclusions

1. The Swollen-shoot virus spreads by the formation of scattered outbreaks. Each of these then spreads radially by the infection of neighbouring trees. Figures are given to illustrate the rate of both types of spread.

2. The history of control measures on the Cocoa Research Station at Tafo is described with data to show the degree of success obtained. In spite of increased frequency of outbreaks, the annual loss of trees has been reduced in 1942 to only a third of the 1940 loss, by checking the tree-to-tree spread.

3. A description is given of an experiment comparing six methods of treating outbreaks. None was completely effective in eradicating the virus in one operation from large outbreaks. It is concluded that since repeated treatment is usually necessary, control can be effected most economically by removing only one ring of symptomless trees and those definitely infected. Outbreaks of less than six infected trees can sometime be checked by rogueing only t showing symptoms.

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VINEGAR FROM SUGAR CANE AND FRUIT JUICES

In an article appearing in *Indian Farming* (October, 1942), S. C. Datta and S. C. Biswas discuss in a semi-popular manner an improved method for the production of vinegar than hitherto available. The method consists of boiling the raw material (cane juice, over ripe fruit extract, gur) with an initial sugar percentage of 18, in earthen or stone jars and inoculating and incubating them firstly with a pure culture of yeast or a yeast starter like toddy or mohua flowers. During the fermentation period which lasts four to six days the jars are kept agitated to prevent mould infection. At the end of the alcoholic fermentation, as noticed by the cessation of frothing the acetic starter is added. This is prepared by the addition of equal quantities of vinegar and fermented liquid and left undisturbed for the formation of the scum or the "Mother of Vinegar". The acetic fermentation is carried out in the shallow earthen utensils and the vinegar matures under these conditions in about 30 days. With an initial sugar content of 16 to 18 per cent. the authors report 7.9, 7.6, 7, 7.5 per cent. alcohol and 6.5, 6.7, and 6.6 per cent. acetic acid production with cane juice, over-ripe banana and jack fruit extracts and 20 per cent. gur solution, respectively.—(*Current Science*, Vol. XI, No.11, p. 451, 1942).

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

The Availability of Phosphates

The availability of the mineral phosphorus compounds in artifical manures is a matter of great importance. The mineral phosphate compounds in these manures and in mixed manures include mono-, di-, and tri-calcium phosphates, mono- and diammonium phosphates, magnesium ammonium phosphate, potassium phosphates, and others. Although many field comparisons have been made, chiefly between pulverized raw phosphates, superphosphates, and concentrated superphosphates, the research work on the economically and potentially-important mineral phosphorus compounds is insufficient and inconclusive because it does not compare these compounds on a sufficient number of the important crops on the major soil-types on which artifical manures are used freely. Economics in the transportation and handling of ammonium and potassium phosphates, and the possibilities of combining by-product ammonia with phosphorus at the coke ovens make apparent the importance of more extensive comparisons. It is desirable further to reduce or eliminate carrier elements of little value so that the definitely needed quantities of secondary and trace elements can be included without sacrificing concentration of the primary plant-food elements. The variations in yields obtained when identical quantities of the same manure are applied by different methods, and particularly when manures in aqueous solution are applied either as "starter-solutions" or as side-applications indicate that a considerable part of the experimental work should be conducted under field conditions, with related chemical studies of crops that take the larger part of the manure used in each important consuming area.—(*Journ. Soc. Chem. Indus.*, Vol. 59. p. 678).

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Soil Colloids

That fraction of the soil which is designated by the term "colloids" is recognized as the seat of many reactions which take place within the soil. Some knowledge of that fraction is therefore of great importance to the student of soil science. In a paper on this subject by H. J. Atkinson published in *Scientific Agriculture*, Vol. 23, No. 5 (1943) a review is presented of some of the theories on the formation, structure and behaviour of the soil colloidal complex. The author states in the summary to his paper "On the assumption that the inorganic colloidal material of a soil is formed by the chemical weathering of original rock minerals, chiefly by means of hydrolysis, Brown and Byers have outlined some hypothetical reactions to explain the formation of different clay minerals such as montmorillonite, halloysite, &c., which are found in the clay fractions of soils, and these reactions are presented. The crystalline nature of the inorganic soil colloids is briefly discussed, together with an outline of the evidence on which the theories regarding their structure are based. Reference is made to the work of Mattson who concludes that the soil colloids are formed by mutual precipitation, at or near isoelectric conditions, between electro-positive or basic sols on the one hand, and electro-negative or acidic sols on the other. The properties of soil colloids are believed to depend to a large extent on the relative proportion of these constituents in the colloid. Mention is also made of Tyulin's study of the organic-mineral gels, in which he outlines a method of separating soil colloids into electro-negative colloids and isoelectric colloids, and of further fractionating each of these groups. It is believed that this method may prove useful in the study of a number of soil problems."

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Effect of Magnesium Deficiency in Grapefruit Trees upon Composition of Fruit

Experimental data from Florida published in the *Proc. Amer. Soc. Hort.*, 40, 1942, 161-4 indicate that magnesium deficiency in grapefruit—Duncan and Marsh—leads to a lowering of the components which are largely responsible for the internal quality of the fruit. The improvement in quality due to the addition of magnesium-bearing materials to magnesium-deficient trees results from the great increase in leaf area and efficiency of the foliage on such trees.

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Tea Leaves as a Maintenance Food for Animals

The replacement of 10-20 per cent. of food concentrates by spent tea leaves (on the 4.1 basis), did not affect the bodily condition or subsequent fertility of rabbits at the Harper Adams Agricultural College. The feeding of tea leaves to rabbits is a practice of small-scale rabbit keepers but experimental evidence of their value has hitherto been scanty.—(*Horticultural Abstracts*, Vol. XII, No. 4, p. 223, December, 1942).

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Experiments with Burial of Cane Trash

According to the *Twelfth Annual Report of the Sugar Cane Research Station*, Mauritius, experiments on the disposal of cane trash have confirmed the results of previous years that no increase in yield resulted from burying trash in various ways as compared with heaping it on the surface of alternate interlines.